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TRANSACTIONS.

NOTE—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CXCVI.

Vol. IX—July, 1880.

THE HUDSON RIVER TUNNEL.

By ARTHUR SPIELMANN and CHARLES B. BRUSH (Spielmann & Brush), Members of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

With Discussion by ASHBEL WELCH, E. S. CHESBROUGH, JAMES B. EADS, JAMES B. FRANCIS, WILLIAM R. HUTTON and CHARLES B. BRUSH.

The Hudson River tunnel is being constructed by direct application of compressed air in accordance with the "Haskin" system of tunnelling in soft material.

Soundings were first carefully taken and the best location agreed upon. A shaft was sunk on the New Jersey shore near the river line, and from the side of the shaft the tunnel was started under the river on such a

grade as never to leave less than twenty feet between the bottom of the river and the top of the tunnel.

In some respects this work resembles that of Mr. Chesbrough at Chicago and Detroit.

As at Chicago, in 1869, a brick shaft thirty feet in diameter was first built on a shoe; the material was taken out from beneath the shoe and from the interior of the ring, and as the shoe sank masonry was added above. As at Detroit, in 1872, it was determined to build two single track tunnels, instead of one tunnel large enough for a double track, for several reasons. The two single track tunnels require less excavation and brick work. The calculations show that to build a single double track tunnel twenty-four feet high and twenty-six feet wide in the clear under the river, would require walls three feet in thickness, and would necessitate for each running foot of the tunnel

28 cubic yards of excavation,
2,200 pounds of iron for the shell,
5,540 bricks laid in cement.

While to build two single track tunnels fifteen feet ten inches wide, and seventeen feet ten inches high in the clear, would require only two feet thickness of walls, and would necessitate for both tunnels

26 cubic yards of excavation,
3,000 pounds of iron for the shell,
5,040 bricks laid in cement.

In addition to its economy of material, the economy and ease of working a face at the heading of three hundred and forty-six square feet required in the single tunnels over that of seven hundred and fifty-four square feet as required in the double track tunnel, and the fact that the smaller tunnels are required to support eight feet less head of water and silt than would be the case with the larger tunnel, make the single track tunnel system in every way preferable for this work.

Unlike the Chicago shaft, however, the New Jersey shaft has been sunk sixty feet in depth instead of thirty feet, and the thickness of the walls at the bottom of the shaft is four feet instead of two feet nine inches. Unlike the Detroit work, this work requires no intricate system of timbering, and no drainage tunnel is proposed, it being kept entirely free from water by compressed air.

THE SHAFT.

Form	Circular.
Outside diameter bottom	38 feet.
Inside diameter	30 feet.
Depth	60 feet.
Thickness of wall at top	2 feet 4 inches.
Thickness of wall at bottom	4 feet.
Batter outside	20 inches.
Weight of shoe	24 tons.
Total weight of structure	1,340 tons.

THE SHOE WAS SUNK THROUGH

Loose ash filling	5 feet.
Tenacious silt	50 feet.
Sand	5 feet.

The shoe is made of ten inches by twelve inches yellow pine, bolted together by drift bolts in ordinary ship work style. It is four feet high and four feet wide on the top with a cutting edge of boiler iron. The brick work of the shaft was laid in Rosendale cement, except the false work on each side of the shaft, elliptical in form, twenty-four feet high and twenty-six feet wide, which was to be eventually removed to make way for the tunnel and approach. This false work was laid in common mortar and caused some trouble. During the process of sinking the shaft that portion of the false work on the east face was forced out of its position to such an extent as to require interior bracing to hold it in place, the projection at the top of the false work amounting to about seven inches, and running out to practically nothing at the bottom.

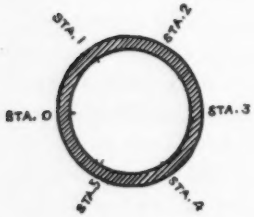
An hexagonal collar brace, of ten by twelve inch yellow pine, was finally adopted as being the most advantageous and as exerting an equal pressure at each joint. Four of these were placed in position, and were found to work very satisfactorily; they not only answered the purpose of braces, but acted as well for floor timbers, supporting the series of platforms which were required from time to time.

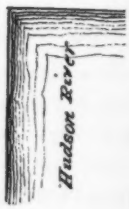
The shoe was placed in position November, 1874, after an excavation of about five feet below the surface of the loose filling, and the sinking of the shaft continued until December, 1874, when an injunction was obtained by the Delaware, Lackawanna & Western Railroad Co. against

the further prosecution of the work. Litigation continued until September 18th, 1879, when the work was resumed. At this date the shoe was about 14 feet below mean high water.

The settlement of the shaft was not uniform The greatest difference of level of the sides of the shoe amounts to one foot. This inequality was not due to want of homogeneity in the soil, but rather to external circumstances.

It was found that the hoisting engine by its vibrations caused that part of the sinking shaft nearest it to settle faster than the other part. The engine was thereafter moved from time to time, and the settlement became more nearly equal. The following table shows the actual settlement from day to day of the different sides of the shaft by giving in feet and hundreds of feet the depth of the shoe below mean high water at different dates.





1880.	STATIONS.					
September.	0	1	2	3	4	5
18	14.13	14.43	14.43	14.33	13.93	13.83
19	14.23	14.53	14.73	14.83	14.53	14.43
20	16.63	16.73	16.93	17.03	16.93	16.73
22	19.63	19.63	19.13	18.83	18.93	19.33
23	21.93	21.73	21.13	28.83	21.13	21.73
24	24.13	23.73	23.13	22.93	23.33	24.03
25	26.13	25.63	24.93	24.73	25.03	25.93
26	28.53	27.93	27.13	27.03	27.63	28.33
27	31.13	30.63	29.73	29.53	30.03	30.93
29	31.73	31.18	30.28	30.13	30.73	31.53
30	34.55	34.03	33.03	32.73	33.33	34.33

1880.	STATIONS.					
October.	0	1	2	3	4	5
1	36.47	35.96	34.95	34.54	35.08	36.13
2	38.05	37.58	36.51	36.03	36.50	37.56
3	39.08	38.68	37.53	36.98	37.43	38.52
4	41.82	41.54	40.43	39.81	40.15	41.52
5	44.11	43.92	42.82	42.15	42.42	43.41
7	47.00	46.91	45.86	45.16	45.36	46.28
8	49.14	49.07	48.00	47.26	47.42	48.36
9	49.24	49.19	48.11	47.38	47.54	48.47
10	49.33	49.27	48.22	47.50	47.67	48.67
11	49.96	49.91	48.91	48.22	48.36	49.23
15	50.32	50.28	49.31	48.67	48.17	49.59
18	52.07	52.10	51.23	50.57	50.63	51.39
25	52.77	52.82	52.01	51.41	51.47	52.15
28	53.46	53.43	52.74	52.27	52.42	52.96
29	53.56	53.53	52.77	52.43	52.48	53.16
30	53.89	53.84	53.20	52.77	52.95	53.49
31	54.07	....	53.38	52.95	53.19	53.64
November.						
3	54.38	54.37	53.70	53.37	53.45	53.95

*On November 3d, 1879, the shoe was in position fifty-four feet below mean high water, or sixty feet below the surface, a settlement of forty feet in forty days, or an average of one foot per day.

The sand bed on which the shoe rested was saturated with water. During the sinking of the shaft all the water that came in was easily pumped out with an ordinary hand pump, but when the sand stratum was encountered, water commenced to pour in at the rate of about two hundred gallons per minute. An Andrews' pump, capacity three hundred gallons per minute, and a Pulsometer, capacity one hundred gallons per minute, were used alternately to keep the water down while making the excavations.

The greatest difficulty was that the inflowing water carried with it both sand and silt, thus not only increasing the amount of excavation but undermining the soil surrounding the exterior of the shaft.

On November 3d, 1879, when the shoe was finally in position the work of putting in the concrete bottom commenced.

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*November 1st, 1879, the writers were appointed engineers in charge of the work.

An open slat wooden curb four feet six inches in diameter at the bottom, two feet in diameter at the top, and four feet high, lined with dry brick, was first sunk to its full depth in a convenient portion of the bottom of the shaft, the bottom of the curb resting about two feet in a bed of gravel composed of stones about three inches in diameter. A number of pieces of second hand four inch iron pipe were then laid from this well radiating in such directions as to confine the water as much as possible in covered chambers.

On a small portion of the bottom, least exposed to the running water, a foundation of loose, dry stone, from 12 to 18 inches in depth, was roughly but securely imbedded. On this the concrete was placed in layers from 8 to 12 inches in depth. Another adjoining portion of the bottom was treated in the same manner, and thus the water was gradually all confined to the well.

The concrete as laid was 2 feet 6 inches thick in the centre, and from 3 feet to 3 feet 9 inches thick on the sides, the average thickness being about 2 feet 9 inches, the centre of the surface being about 2 feet 6 inches lower than the highest portions of the sides. About 90 cubic yards of concrete were laid, mixed in the proportion of one of cement, two of sand, two of stone, and one of gravel. Each batch furnished about 14 cubic feet, or 3½ barrels of concrete. 163 barrels of cement were used in mixing concrete, and 12 barrels were used neat for stopping bad leaks and floating the surface of the bottom after the concrete had been laid.

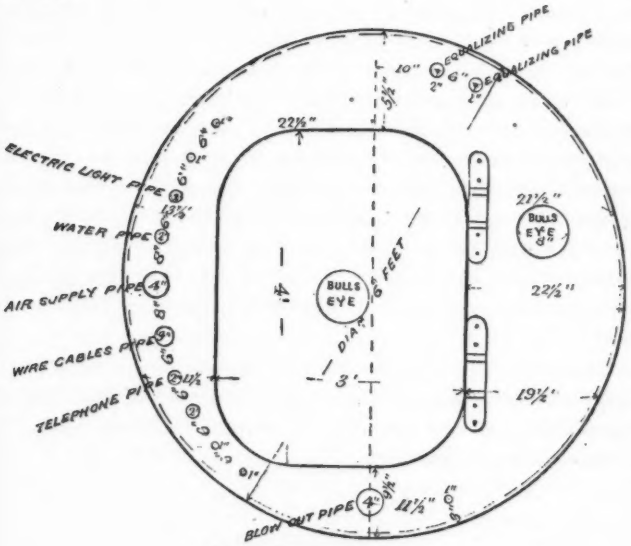
November 7, 1879, the concrete bottom was completed. Time occupied, 36 hours.

After the bottom was laid, the water continued to flow through the well at the rate of about 80 gallons per minute. It was found that the sand came through the well with the water, at the rate of about 4 cubic feet per day. The well was filled with dry stone, but this only partially retarded the sand.

A stand-pipe, 12 inches in diameter, was then carried up from the bottom of the well, for 25 feet, then a reducer for 5 feet 7 inches, then a pipe 4 inches in diameter to above the level of high water. The water rose in the stand-pipe to a level of 9 feet below the surface of mean high water, and then rose and fell in exact proportions, but not to the same extent as the tide in the river, the differences of level in the pipe being about one-third those in the river; this continued until the first rings of

the completed tunnel were built, as hereinafter explained, and the bed-sand struck.

As soon as this bed-sand was struck, the water came into the tunnel from the sand at the rate of about 5 gallons per minute ; the air pressure was then increased, and the inflow ceased ; the water in the stand-pipe, however, began to blow out with great violence, the spray being driven from 15 to 20 feet above mean high water. A cap was then put on the stand-pipe and the water confined. It has ever since been used as a reservoir, from which the water is drawn to mix the cement for the masons, and to dissolve the silt preparatory to blowing the latter out of the tunnel.



END VIEW OF AIR LOCK.

The air lock is entirely of wrought iron. It is horizontal, 6 feet in diameter and 15 feet long. The doors are 3 feet wide and 4 feet high. The shell is made of $\frac{3}{8}$-inch boiler iron, the plates being 3 feet wide and

NOTE.—December 1, 1879, we secured the services as superintendent of Mr. J. F. Anderson to whom Mr. D. McN. Stauffer, C. E., and member A. S. C. E., has referred in his paper on compressed air in tubular foundations, and its application at South Street Bridge, Phila., No. CLXXII., and to whose experience, courage and endurance, a large portion of the success of the work is due.

extending over half the circumference without break. They are double riveted on the longitudinal laps and single riveted on the transverse laps, with ⅞-inch rivets two inches apart from centres, and all laps are carefully caulked. The heads and doors are ½ inch thick. Each head contains 13 pipes ranging from 1 to 4 inches in diameter, all of which run entirely through the lock. In addition one 6-inch pipe has been run through the tunnel end of the lock, emptying through the side of the lock into the bottom of the shaft. These pipes have been found to be very convenient, and are or will be used for various purposes, such as air supply, water supply, electric lights, telephones, blow-out pipes, etc.

There are four bull's eyes, one in each door, and one in each head at the side of the door; those on the sides have been found to be very convenient, but those on the doors are of no practical value for purposes of light. The glass is one inch thick and nine inchs in diameter, the exposed surface being 7½ inches in diameter. The door frame is of 4-inch angle iron, securely riveted to the heads. Each head has five 2-inch braces, 2 feet long, riveted to the shell. The door is braced by strap hinges 3 inches wide, and ⅞ inches thick, extending all the way across the door at a distance of 10 inches below and above the top and bottom of the door, and by two pieces of 4-inch T iron, also extending entirely across the door at a distance of 1 foot 6 inches below and above the top and bottom.

The air-lock is used for the transmission of men and materials, but it has been found to be too small. Other air-locks will be built vertically between the shaft and the river, to receive the material, leaving the present lock for the men alone.

Excavation.

The material through which the tunnel is built is a tenacious silt, weighing about 100 pounds to the cubic foot. It seems to be impervious to both water and air, yet when thoroughly mixed with water, it becomes a semi-liquid mass, which is easily handled.

An opening was made in the side of the shaft to receive the air-lock at the top of the old false work, 23 feet below mean high water. When the silt was first exposed it was stiff, and comparatively dry. It could

be moulded like putty, however, and had the same moist feeling as that material.

After the silt in this opening had been exposed three or four days, it began to soften, and show a tendency to run. The air pressure was then put on, and this tendency was immediately checked.

The first excavation under air pressure was made December 28, 1879. The company hoped at that time to be able to build a single double track tunnel across the river of the same size as the approaches, to wit, 24 feet high, and 26 feet high in the clear. An opening was, therefore, commenced, by excavating around the exterior wall of the shaft, extending the heading a few feet from the shaft. The air escaped somewhat through the brick and between the soil and the wall. Timbering was resorted to to protect the roof, but on January 2, 1880, the excavation only amounted to 15 feet in width, 6 feet in height, and 4 feet in length.

No effort had been made during these four days to protect the surface of the silt from the effect of the air, and the result was peculiar. At first no effect could be observed, but after a few day's exposure little holes about the size of a pin began to develop. A day later slight cracks appeared, a day later these small cracks concentrated into several large cracks, and as the air passed up through them, lumps of the silt from a few inches to a foot in diameter, fell from time to time. At the end of the fourth day, these falls became more frequent, and half a day later the whole had gradually fallen.

We found that these cracks had extended upwards about two feet through the silt to the loose filling above, which had been carried down during the sinking of the shaft, and the water had commenced to flow freely through these cracks in the silt. The effect of water on this silt is different from that on ordinary clay ; the silt in this respect being similar to quicksand. Instead of remaining hard and lumpy, the material, when exposed to running water, dissolves and flows readily with the water.

These experiments gave a very fair idea of the materials to be handled and the difficulties to be encountered. On January 5th, 1880, work was recommenced.

Plates for an iron tube 8 feet long and 6 feet 4 inches in diameter were ordered, the plates to be half an inch thick, 2 feet 6 inches wide and 4 feet long, with 3 inch angle iron flanges rivetted to the four sides of the plate.

While these were being prepared, an excavation was made 30 feet in width, extending from the east side of the shaft about 20 feet towards the river and to a depth of 9 feet below mean high water. The material excavated was all loose ash filling. At the depth of 9 feet below mean high water canvas was carefully spread over the bottom of the excavation and carried a few feet up the outside walls of the shaft. Heavy timbers, thirty feet in length, were then laid across this canvas to hold it in position, and to assist in supporting the refilling which was immediately replaced.

While the roof was falling, on January 2d, the door of the air lock at the tunnel end was closed, and the debris kept it shut. By the use of an hydraulic jack, however, it was forced open about 10 inches, when the water came pouring through the partially open door at the rate of about fifty gallons per minute. Compressed air was then applied and the flow of water checked, the glass bull's eye in the door knocked out and through this opening sufficient material was excavated to enable the workmen to open the door.

On January 13th, 1880, the air was again put on at 8 A. M., and on January 16th, at 5 P. M., the first ring in the temporary entrance to the tunnel, 6 feet 4 inches in diameter and 4 feet in length was in position. At noon on the same day the second ring was commenced; at 9 A. M. on the following day it also was finished.

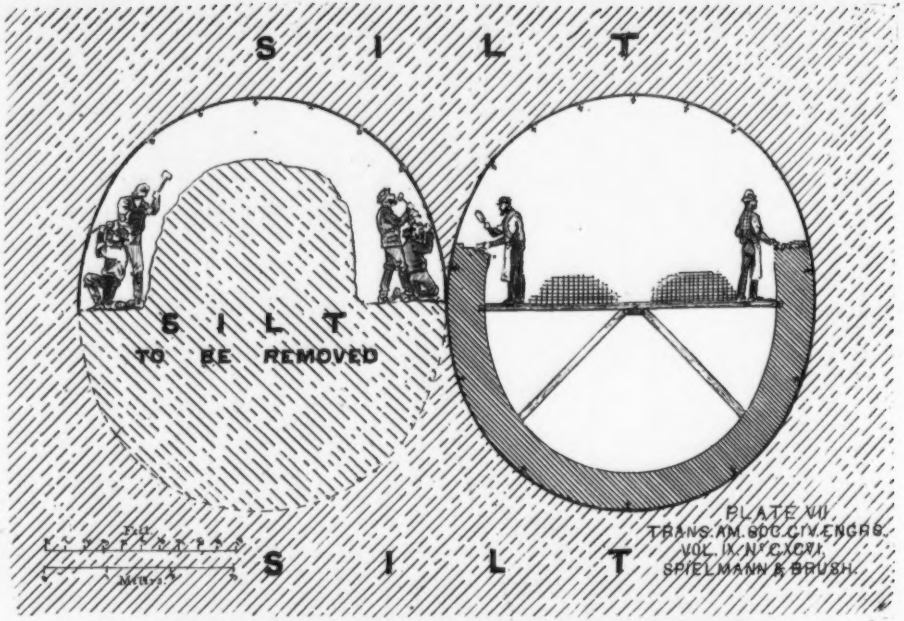
Iron Shell and Brick Lining.

A series of iron rings were then built 2 feet 6 inches wide, each succeeding ring increasing about 18 inches in diameter until the full diameter of the tunnel was reached. These rings were joined only at the top which descended so as to meet the proposed grade of the tunnel.

February 3d the 11 rings of the temporary work were in position, and the irregular spaces between the rings forming this entrance were temporarily filled in with concrete.

February 9th the first plate was placed in position in the most northerly of the permanent tunnels under the river, and since that time the work has been gradually systematized and has gone on rapidly and smoothly. During the first week the advance was hardly 1 foot per day, but at present the rate is 4 feet in each 24 hours.

The plan of advancing the work has been as follows:



SECTION OF TUNNELS UNDER THE HUDSON RIVER

IN PROGRESS

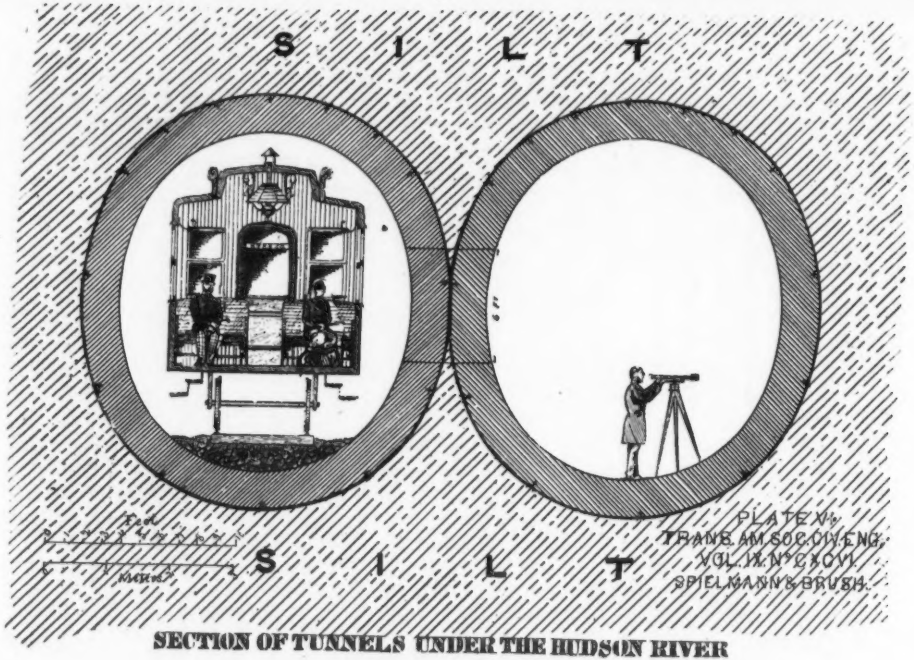


PLATE VI.
TRANS. AM. SOC. CIV. ENG.
VOL. IX. N° CXCVI.
SPIELMANN & BRUSH.

SECTION OF TUNNELS UNDER THE HUDSON RIVER

WHEN COMPLETED

To construct a series of iron rings each 2 feet 6 inches wide, well bolted together, and forming, when completed, an iron shell or tunnel in itself, then to follow up immediately with the lining of brick.

The rings in the permanent tunnel are composed of plates of wrought iron ⅜ of an inch thick, and 2 feet 6 inches wide. There are 14 plates in every ring, the 6 top plates 3 feet in length and weighing about 170 pounds each, and the remaining plates 6 feet in length and weighing about 320 pounds each. These weights include the 3 inch angle iron that is rivetted on the sides and ends of each plate, the rivets being ½ an inch in diameter, and placed 6 inches apart from centers. The plates are fastened together, so as to break joint, with ¾ inch bolts 9 inches apart from centres.

The bricks are hard burnt, of good quality, laid in the best Rosendale cement, in the proportion of 1 of cement to 1½ of sand.

The Heading.

The heading is advanced as follows :

The face of the heading is always the exposed silt which is so stiff when under the air pressure, that it can be cut in benches as a series of garden terraces, and also into steps rising from one terrace to the other. An average slope of about 45° is usually left on this face, and the excavation for and the building of the rings always commence at the top of the tunnel. Usually 5 rings are building at the same time, each one of the 5 rings towards the rear being more nearly completed than the ring directly in front of it. The first 4 plates require some slight support, but the others are easily held in position by the air pressure, the bolting to adjoining plates, and the support received from resting the plates directly on a bed of the silt.

The bracing and timber ordinarily used in tunnelling are not required on this work. Some 4 x 6 inch timbers are thrown across from the end flanges of the iron plates in order to have a platform for convenience of access to the different parts of the work, but these are not relied upon as braces.

The support received from compressed air is not simply a theory. A short time ago when the heading was about 150 feet from the shaft, the bottom being 54 feet and the top 32 feet below mean high water, and a pressure had been used of 18 pounds per square inch, every thing

appeared to be working so well that it seemed as though a less pressure might suffice; it was therefore reduced to 15 pounds per square inch. Within a few hours the timbers in use for platforms began to show signs of buckling, some of them bending as much as 2 inches. The pressure of 18 pounds was then resumed, and has since been maintained and no appreciable settlement of the plates has been observed up to this time.

The material excavated from the tunnel is not carried through the air lock. About half the silt is blown out of the tunnel. It is first reduced to a semi-fluid consistency by mixing 4 cubic feet of silt with 1 cubic foot of water, around the open mouth of a 6 inch pipe which extends from the tunnel through the air lock to the lower part of the working shaft. A stop cock on this pipe is then opened and the air in the tunnel allowed to escape and carry the silt with it. The remaining half of the silt is removed to the completed portion of the tunnel, where it will be allowed to remain until the approaches are completed, when it can be more economically removed by cars. There is still another reason for leaving this silt in the tunnel. It is known that a rod can be easily driven through the silt provided it is not allowed to remain at rest any length of time; when this occurs, however, the silt becomes so compact around the rod that in a few days it is almost impossible to move it. In many of the piers we have along our Jersey City and Hoboken shore fronts, the piles have been simply pulled down their full length, from 50 to 70 feet, by an ordinary tackle. They do not rest on hard bottom, and if they are a little too low for the string piece, are immediately raised in the same way, and in a few days the friction of the silt becomes so great that they cannot be moved. By leaving sufficient of the waste material in the tunnel so that the specific gravity of the iron shell and brick work added to that of the silt in the tunnel, shall equal the specific gravity of the total excavated material, there is no disturbance in the surrounding silt. The latter gradually settles around the outer portions of the tunnel and holds it fast in position.

Atmosphere in the Tunnel.

Records taken to date show that the thermometer in the tunnel always stands about the same, 72° Far.—whatever the temperature outside may be. At the bottom of the heading it is about 66°, and at the top 50 feet back from the silt it is about 76°. The air in the tunnel is very good and pure since the electric light has been introduced, but the

lime water test is still continually applied. Ventilation is provided by continually forcing pure air into the tunnel and forcing the foul air out with the silt through the blow-out pipe and through the pipe furnishing the air neccessary to run the force-pump, by lockage and to a slight extent by leakage along the bulkhead and the temporary entrance to the tunnel.

No injurious effect has been observed upon the workmen ; on the contrary, they seem to rather enjoy their daily air bath.

Care is taken to avoid the employment of men of irregular or dissipated habits and of men of over 50 years of age, and violent exercise is discouraged on their emerging from the lock.

The work is prosecuted day and night in three shifts of eight hours each, but at the end of four hours the men come out into the open air for meals or for changes of shifts.

The electric machine and lamp is furnished by the United States Electric Lighting Company, under Hiram S. Maxim's patents. It lights up the tunnel very brilliantly in the immediate vicinity of the lamp, but at a distance of from 75 to 150 feet, however, depending upon the clearness of the atmosphere in the tunnel, its illuminating power is to a great extent lost, and candles or other lights have to be used. About 2½ horse power is required to drive the electric machine supplying one lamp. The generator makes 1 050 revolutions per minute. When two lamps are running 5 horse power is required to cause the same number of revolutions. The Wallace coppered carbons are used in the electric lamp. They are 12 inches long and ⅝ inch in diameter.

The candles used are the ordinary coach candles, 7½ inches long and 1¼ inches in diameter, weighing about 5 ounces. By experiment last week it was found that these candles burned 1 inch in 1 hour and 40 minutes in the tunnel. The same candle was then lit outside of the tunnel and took exactly the same time to burn the next inch. This experiment was repeated with another candle and the same result obtained.

We have two air compressors which we use alternately. First, a double acting Clayton compressor with two air and two steam cylinders, each 10 inches in diameter, and 13-inches stroke. It compresses theoretically 2.53 cubic feet of normal air at each revolution, but, practically, about ⅓ of this amount is lost, and we only obtain 1.65 feet of normal air at each revolution.

Second, an Ingersol rock drill compressor, also double acting, but

with single cylinders, the diameter of the steam cylinder being 10 inches and of the air cylinder 12 inches, and the stroke of both 12 inches. Theoretically it compresses 1.57 cubic feet of air at each revolution, but as in the case of the Clayton there is here also a loss of about ⅓, and we only obtain 1.05 cubic feet of normal air at each revolution. We are now delivering into the tunnel each 24 hours, about 83,000 cubic feet of normal air under a pressure of 18 pounds per square inch. In order to accomplish this, the average number of revolutions of each compressor, when running alone, is for the Clayton, 35, and for the Ingersoll, 55. This amounts to about 125 cubic feet of normal air per hour to each man at work in the tunnel. All this air is doubly washed, first as it is drawn into the air cylinders of the compressors, and again as it is passed through the water into the lower portion of the air reservoir.

About 11 horse power is required to run the Clayton compressor at the speed given above, and 8 horse power for the Ingersoll. Each require about 75 pounds pressure of steam on the boiler and 34 pounds on the piston.

Last week, telephonic communication was established between the tunnel and the surface. The Bell telephone and the Blake transmitter, are used, and so far they have worked very satisfactorily.

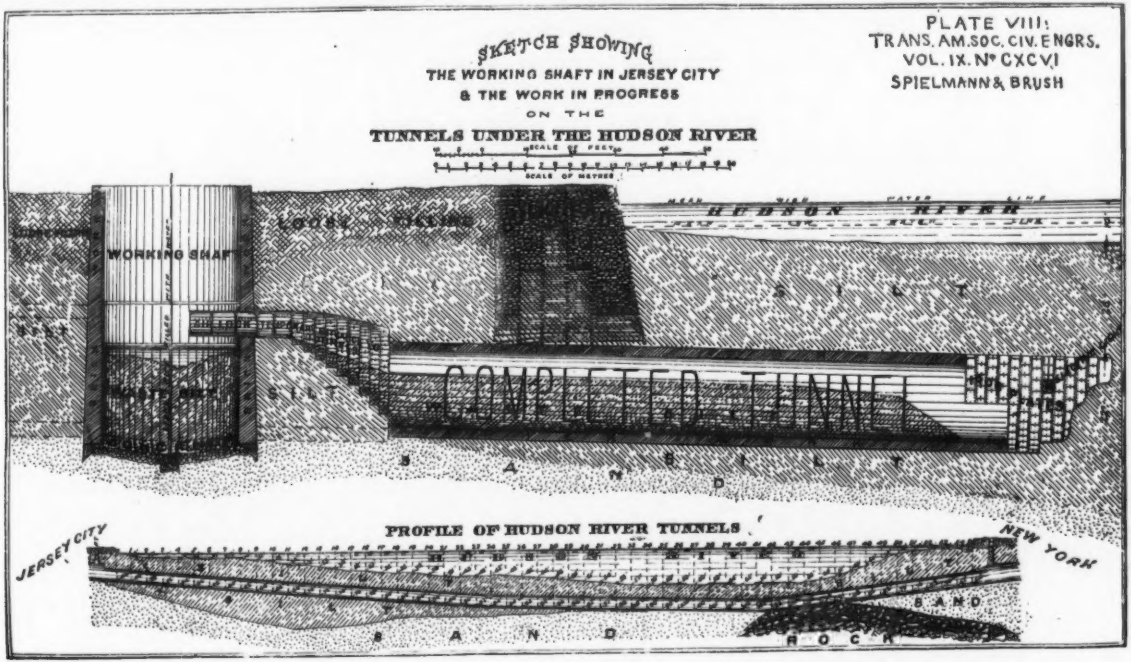
Up to this time the work has been confined to the shaft in Jersey City, the temporary entrance to the tunnel, and the north tunnel under the river, which latter has now been driven 230 feet from the easterly face of the shaft. It is proposed, however, to immediately commence the south tunnel and carry on both simultaneously, also to build the connection between the shaft and the double tunnels. The work on the New York side has necessarily been delayed on account of lack of the requisite legislative permission. This having been obtained it is proposed to start the shaft in New York without delay, and to work both tunnels from thence under the river to meet those coming from New Jersey, and to build the New Jersey and New York approaches.

Details of the cost of the work, the location of the New York approaches, and the uses to be made of these tunnels have not been considered in this paper, but they will be presented on some future occasion if so desired by the Society.

To Dewitt C. Haskin is due the credit of originating and carrying into successful operation this peculiar system of tunneling.

PLATE VIII.
TRANS. AM. SOC. CIV. ENGRS.
VOL. IX. N° CXCVI
SPIELMANN & BRUSH

SKETCH SHOWING
THE WORKING SHAFT IN JERSEY CITY & THE WORK IN PROGRESS ON THE TUNNELS UNDER THE HUDSON RIVER



Discussion of the above Paper at the Twelfth Annual Convention.

James B. Eads in the Chair.

The Chairman.—Gentlemen of the Convention, a discussion of this paper is now in order.

Ashbel Welch.—I would like to ask Mr. Brush whether the water that rises and falls as the tides rises is salt or fresh?

Charles B. Brush.—The water is brackish.

E. S. Chesbrough.—I would like to ask how often soundings were taken across the river?

Charles B. Brush.—Every 100 feet.

E. S. Chesbrough.—I would like to know also if the soil is uniform silt.

Charles B. Brush.—It appears to be. I will state that perhaps I am answering somewhat hastily in regard to these soundings. They were taken by another party during 1875. I have tested the depths of water since that time in various places—made rough tests—so that I might be sure the original soundings were approximately correct. I have not made a complete series of borings myself as yet.

The Chairman.—I would like to inquire what is the difference in the pressure of the water and the compressed air? I understand that 18 pounds is all you use. The weight of water, due to the height above the place that you are operating, is not balanced by 18 pounds, I think?

Charles B. Brush.—No, sir; it is not. I have not made an exact calculation at this particular point. We found, however, that it was not necessary to use the amount of air sufficient to support a column of water equal in height to the depth of the tunnel, on account of the tenacious character of the silt itself.

The Chairman.—What is the depth you are working at now?

Charles B. Brush.—The bottom of the tunnel is 58 feet below mean high water, and height of the tunnel is practically 22 feet, thus leaving 36 feet overhead, 10 feet of which is water and 26 feet silt.

The Chairman.—58 multiplied by the decimal .44 would give the pressure of water then.

Charles B. Brush.—Yes.

James B. Francis.—How does this material differ from clay? It is

called silt, and has some of the characteristics of clay; I would like to know the distinction?

CHARLES B. BRUSH.—As we said in our paper, in some respects it resembles quicksand; when water is applied it commences to dissolve, and is easily blown out of the tunnel. Clay, on the contrary, does not readily dissolve, water runs over it, and in this respect there is a difference.

THE CHAIRMAN.—Does not the word "silt" comprise all fine silty matter which is carried in suspension in rivers?

CHARLES B. BRUSH.—I presume it does. We use the term as the best to apply to the material. It is a deposit that is made, the accumulation of ages, from the flow of the river. I know of no better term.

THE CHAIRMAN.—It is that portion of alluvium which is distinct from gravel and boulders?

CHARLES B. BRUSH.—Yes.

THE CHAIRMAN.—A material that is moved by rivers?

CHARLES B. BRUSH.—Yes.

THE CHAIRMAN.—That is my understanding of it, but I am not sure that I am right.

CHARLES B. BRUSH.—Yes. I did not intend in the term that I employed to cover sand or gravel or anything of that kind.

ASHBEL WELCH.—There is this marked distinction, sir, between silt of that neighborhood and clay; I have put gravel, heavy gravel, upon this silt; it has sunk through it 70 feet down to the rock. I have put the same gravel on ordinary clay, and it would not sink at all. (A specimen of the silt referred to was shown to Mr Welch, who said,) "Ah, it is an old acquaintance of mine."

E. S. CHESBROUGH.—I would ask Mr. Brush if he has tried whether a man can run his hand or arm through this silt up to the shoulder with comparative ease.

CHARLES B. BRUSH.—He can do that in the surface of the silt on the bed of the river but not below it. Our experience with this silt is a little different from that of Mr. Welch. We find that as soon as heavy filling, such as gravel, is put upon the silt, the silt is compressed and the gravel sinks. We have never found, however, that the heavy filling went through the silt to the hard bottom; it always sank until the compressed silt was sufficient to uphold the weight above it; it has not been our experience in this particular silt to have the heavy material go down

through it. In filling in the streets, over the salt marsh between the Palisade Ridge and the upland portions of Jersey City and Hoboken, we encounter this silt from 20 to 100 feet in depth. We find that the filling on these streets has sunk from 10 to 30 feet in depth. The sides of the silt are forced up and the heavy filling sinks down until the specific gravity of the two are equal, and then it stays there. In such cases the silt is compressed and becomes very hard indeed. I recall a case in point, the plank road from Hoboken to Jersey City. This road was built some 100 years ago. A light filling was put on and it sank a short distance; from year to year more filling was put on, which sank down about 20 feet in the deepest portions of the silt. In one part of the road where the silt was from 15 to 20 feet in depth and where the filling had sunk from 6 to 8 feet, we opened a trench for the purpose of building a sewer; after cutting through the filling, the silt was found to be so hard that we actually had to use picks to get it out. So also with the silt that we are meeting at the tunnel heading, it is absolutely impossible to run the arm into it, as Mr. Chesbrough suggests. On the contrary as you strike it, it gives out something like a ringing sound, and it is sufficiently compact to enable us to cut steps and terrâces in it.

Ashbel Welch.—I quite agree with Mr. Brush; the only difference between us is this. I suppose on a street 40 feet wide where the weight is put on equally, it will compress as he says and go down to a certain distance and stop, but the case I speak of is a narrow ridge of gravel, put that on and it will go down to the hard bottom, and if in filling a street we fill one side too much, that side will sink down and become unequal.

E. S. Chesbrough.—My reason for asking the question with regard to the ability of a man to put his arm into the silt is because as long ago as 1864, I supposed it might be possible to do what Mr. Haskins now appears to have succeeded in doing, in going through that silt. I had charge of a work in which I feared that difficulties of that kind might occur, and that it might be necessary to resort to the pneumatic process, and I then thought it might be possible to use it horizontally.

The Chairman.—You allude to the Chicago Tunnel?

E. S. Chesbrough.—Yes, sir; the first one. But I found in very soft clay, where a man could run his hand and arm to the shoulder in it, there was no great difficulty in going through it, if the manager was careful and if all the workmen were on the alert, and every precaution

was taken to secure the work as they advanced, but if there was any quicksand, in a short time the ground would become, as they say, demoralized, and then it was exceedingly difficult to go on with the work. I had occasion a few years ago to try the horizontal pneumatic process, as I might call it, that is, the pneumatic work horizontally in what I would call slush. It was a perfect failure, and we came very near losing the men who were under the air-lock. It is for this reason that I feel such an intense interest in this work. I know that it is possible to go through very soft ground if the men, the engineers and all concerned are very careful to secure everything as they go, but if the ground happens to be very watery, very soft, or as I would call it "slushy," I have doubted whether the pneumatic process would be successfull. Still I know an engineer ought not to call anything impossible, and therefore I have looked with great interest to the labors of our friends here in the Hudson River Tunnel.

Charles B. Brush.—I would say that the slushy material through which we had to go at the top is entirely different from that which has been spoken of. For the space of a few feet on the top of the river it is soft for 3 or 4 feet perhaps, but beyond that it begins to grow quite consistent, and when we get down 15 to 20 feet we find a very stiff and tenacious bed of silt, and this continues all the way across.

William R. Hutton.—My notes on electric lighting are now more than a year old, and probably contain nothing new to you. I give some points referred to in a conversation with Mr. Brush, in case they may be of use.

A single light from a Gramme Machine, requiring 2½ horse power, lights in the open air a radius of 100 metres. A factory room 5 metres high, 24m. wide, 42m. long, containing 160 looms, is thoroughly well lighted by 6 Gramme lights, the light being reflected from a smooth white board ceiling; having this advantage over gas, that the colors are not affected by it, and the different shades can be matched as well by night as by day.

One such light is sufficient for 500 sq. metres, of shops where minute work is executed, 500 to 1000 sq. metres of machine shop, 2000 sq. metres of out door work, earth-works, masonry, &c., &c.

When it is necessary to throw the light in one direction only, through an angle not greater than 180°, the diffuser designed by Van Malderen may be used; its a parabolic mirror—the light in the focus—the front

closed a short distance from the focus by a dead glass, which receiving the parallel rays from the reflector, enlarges and diffuses them so as to illuminate all the space in front of it.

At the railroad station "du Nord" in Paris, the light proper is concealed from view in the hall by an inverted cone of ground glass, which reflects the arrested rays towards the ceiling along with the other rays. The ceiling being white, a diffused and nearly vertical light is distributed through the room.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

NOTE.—This Society is not responsible, as a body, for the facts and opinions advanced in any of its publications.

CXCVII.

Vol. IX.—July, 1880.

AMERICAN NATURAL CEMENT.

By F. O. NORTON, Fellow of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

In the course of a large number of experiments made upon the strength of cements, the writer has obtained certain comparative results which he has been requested by a number of the Members of this Society to present at this time.

The experiments referred to were made daily during the season of

1878, at the works of the writer, and show the results from breaking 5 824 test briquettes. The results of a portion of the test work in 1879 are also presented. It may be proper to refer for a moment to the circumstances under which this large number of tests was made.

For many years the manufacturers of the American cements sold under the general name of Rosendale cement, had permitted the standard of their productions to run very low. There was an active demand for cement and there was not, until within the last eight years, that care in selection or knowledge of appliances for testing on the part of large users of cement which now, fortunately, more or less exists. The introduction of the foreign Portland cement, at about that period, afforded an article, of course at a much greater price, but also of decidedly better strength than the low grades of American cement which were really the majority of those then in the market.

Since that time there has been a marked improvement in the quality of the Rosendale cements, effected by care and improved appliances in their manufacture.

The writer knows that a high standard for American cements can be secured, but only by determined effort and careful attention. Unfortunately there is to-day considerable cement of a very inferior quality offered as Rosendale cement, much to the disadvantage of the effort to maintain a standard of high strength.

The principal deposit of the magnesian lime-stone producing a cement possessing hydraulic energy occurs in the Town of Rosendale, Ulster County, New York. It was first brought into use about the year 1823, in the construction of the locks and other masonry of the Delaware and Hudson Canal, which passes through that county. Its production has gradually increased until there are now made from one million to one million and a half barrels in each season, of about eight to nine months, or during the period of navigation on the Hudson River between Rondout and New York. It is the chief industry of a large section of country, its reputation is extended and it is sold in most of the large markets of the United States.

In the management of one of the large works engaged in quarrying and manufacturing this cement, the writer instituted the system of tests referred to, for the purpose of securing uniformity in the product of those works, and of making sure that the standard of the cement made should be what was desired.

These tests were made daily at the works at Binnewater, Ulster county, New York, during the season of 1878, beginning April 1st, and ending November 30th, a period of eight months.

At several times each day a number of test briquettes were made from the cement manufactured during that day. These briquettes were mixed in two ways; namely, for one set the cement was mixed with sufficient water to form an ordinary stiff mortar which was pressed into the moulds with a trowel and smoothed off; for the other set a very dry mixture was made, following the formula adopted by J. Herbert Shedd, member A. S. C. E., in making his experiments. Both mixtures were left in the moulds a few minutes, and were then pressed out with a wooden plunger upon a sheet of tin or sheet iron, and left in the air for thirty minutes; they were then put in water and left in water until broken. The temperature of the water either for mixing or in the setting tanks was not closely noted, but spring water was used, the temperature of which varies very little during the whole year. In some cases the water in the setting tanks was changed frequently, in some cases very seldom, while some of the briquettes were kept in a flowing spring for twelve months. The results in each of these cases did not materially vary.

From each day's production one briquette of the wet mixture and one briquette of the dry mixture were broken at intervals after the mixing of the briquette, of respectively twenty-four hours, seven days, one month, two months, three months, four months, five months, six months, seven months, eight months, nine months, ten months, eleven months and one year.

There were during the season, the kilns not being drawn on Sunday, twenty-six briquettes of each mixture tested for each of the above periods, including the one year test or for the eight months of the season's production, 208 tests of each mixture for each of the fourteen periods, making 5 824 briquettes made and broken of the season's production. In other words, there were each month twenty-six days' production, and fourteen briquettes of each mixture each day, giving the total for the eight months of 5 824.

The curves presented have been drawn from the tabulated results, precisely as recorded by the testing machine, with no omissions or alterations. Many briquettes broke low on account of mechanical defects in their construction or from cross strains resulting from unevenness in their form, probably due in many cases to slight settling of the mortar

after removal from the mould and consequent imperfect fitting in the clutch. Some variations in the results are also probably due to inequalities in setting, to the season of the year when the briquettes were mixed, and to the temperature of the water or air before breaking. Certain individual results shown in the tables are worthy of attention, but of course the main interest lies in the general and average results shown by the curves presented herewith, which are given in accompanying* Plate IX. These prove conclusively that a cement of high standard strength can be continuously produced in large quantities from the quarries in Ulster county, New York. This, of course, can only be done by proper selection of the stone and careful attention to the manufacture. Even the minimum results are higher than has generally been supposed practicable averages for Rosendale cement.

The writer considers these 5 824 specimens, fair samples of the production of the Binnewater works during the season of 1878, amounting to nearly 150 000 barrels of cement.

An incidental result of these tests is of great interest. There has been a general impression that the use of a very small amount of water in mixing cement gave greater resulting strength than when sufficient water was used to form a paste of the consistancy of stiff mortar. The tests here recorded and shown on Plate IX, prove that the dry mixture does give decidedly higher tensile strength in 24 hours after mixture, and that it continues to be stronger than the stiff mortar for some three months. But after that time the reverse becomes true: the curve of strength of the stiff mortar rises to and passes above that of the dry mixture and the strength of the cement mixed as a stiff mortar continues greater than that mixed with very little water, and this is the case continuously thereafter.†

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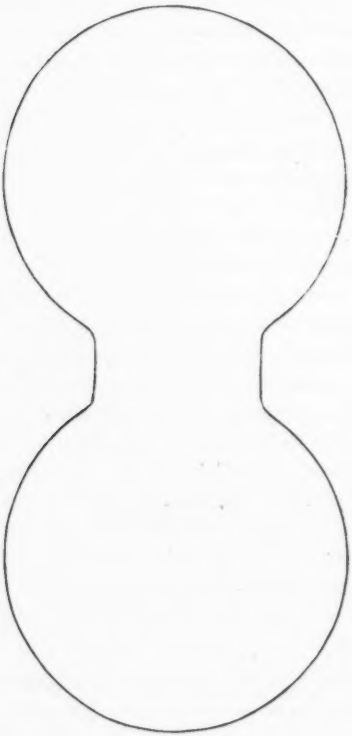
* Tables giving the record of tests for each day, and also monthly plates giving the curves of these tests as drawn from the records were presented with this paper. The published Plate (IX.) shows the average curves for the season. The publication of these tables of daily tests and the monthly plates is omitted for the sake of brevity.

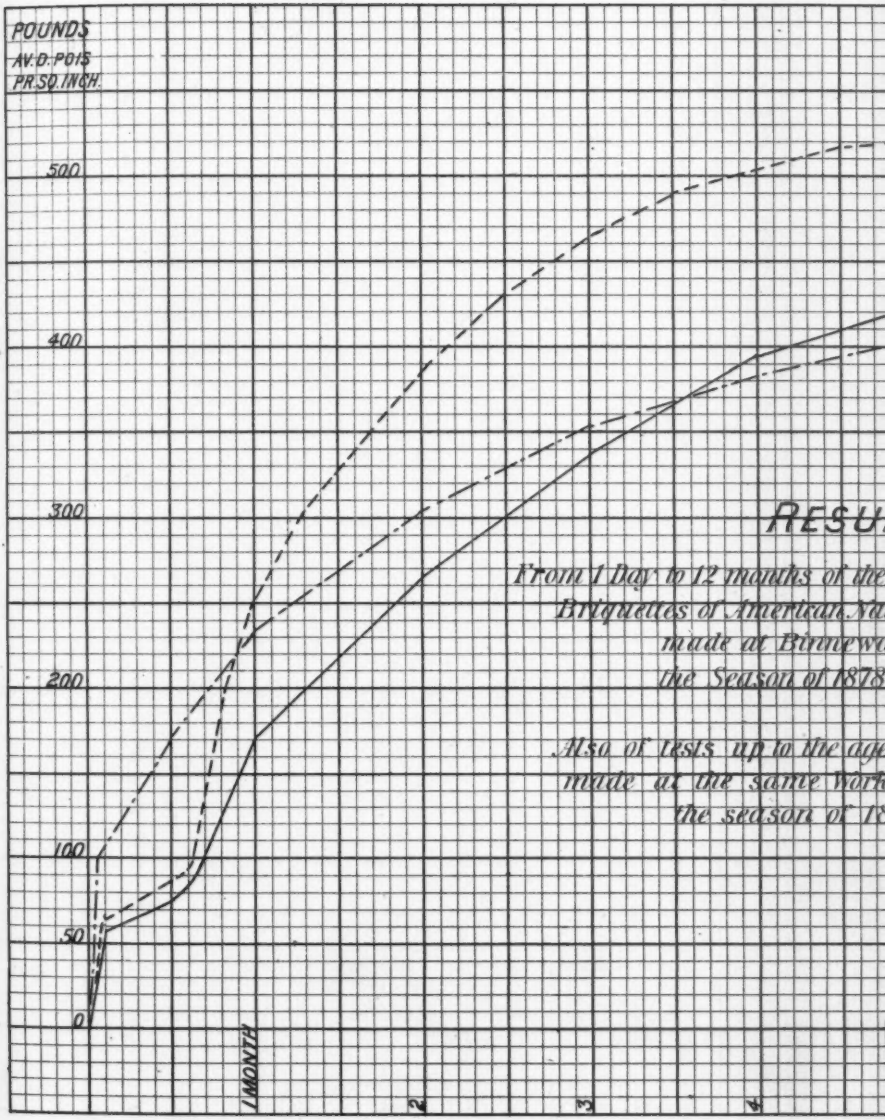
† The expression "stiff mortar" does not refer to thin mortar, but to a mortar made with only such an amount of water as to secure a stiff, plastic paste similar to plasterers' mortar. Water used in excess will certainly weaken the mortar.

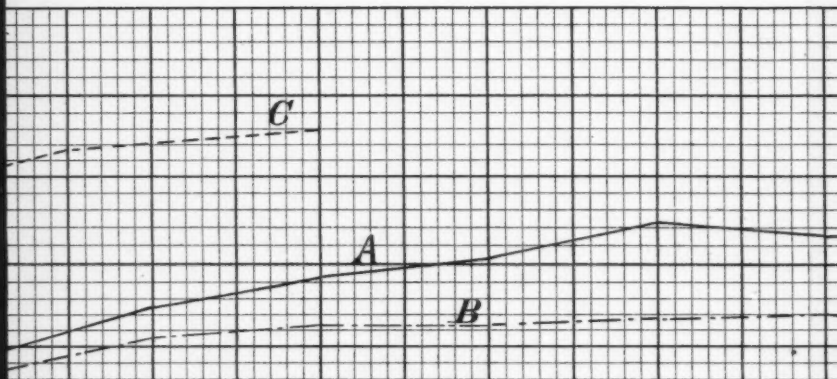
The shape and size of the brass mould used is as shown in the accompanying sketch. The breaking area is one inch square.



The machine used for breaking was built by Riehle Brothers, of Philadelphia, who exhibited its mate at the Centennial Exposition.

During the year 1879, a mould was used producing a briquette of the same form and size as those of 1878, but this mould was made of wood


POUNDS
AV.D. POIS
PR.SQ.INCH.
500
400
300
200
100
50
0
1 MONTH
2
3
4
RESU
From 1 Day to 12 months of the
Briquettes of American Na
made at Birnewo
the Season of 1878
Also of tests up to the age
made at the same work
the season of 18



RESULTS OF TESTS

hs of the Tensile Strength per Square inch of 5824
rtland Natural Cement (ROSENDALE)
Bonnie water Works during
n of 1878.

n the age of six months of Cement
ine Works during
on of 1879.

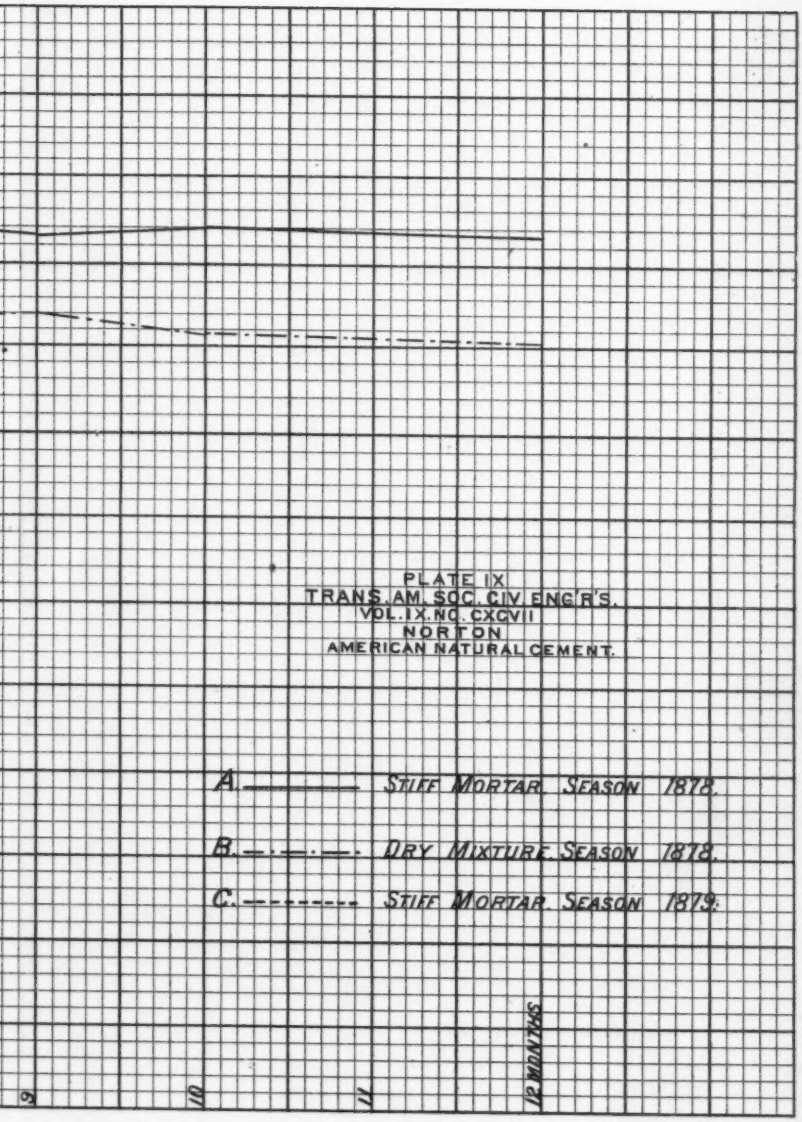
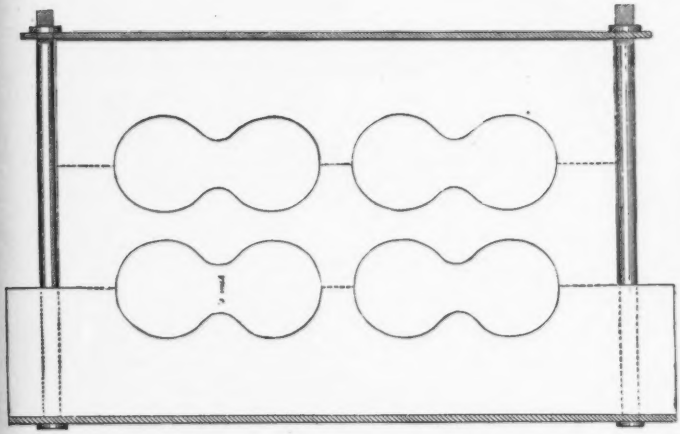


PLATE IX
TRANS. AM. SOC. CIV. ENG'R'S.
VOL. IX. NO. CXCVII
NORTON
AMERICAN NATURAL CEMENT.
A. ——— STIFF MORTAR. SEASON 1878.
B. —·—·— DRY MIXTURE. SEASON 1878.
C. - - - - - STIFF MORTAR. SEASON 1879.
9
10
11
12 MONTHS

and was constructed so as to be unlocked and moved away from the briquette. (See sketch.)



This obviated the necessity for pushing the briquette out of the mould, and also permitted its remaining in the mould longer than with the metal one. The result has been greater uniformity in the form of the briquette, more accurate fitting in the clutch, and consequently less liability to cross strains. During 1879 the tests were made upon briquettes of stiff mortar only, under the same general method as has been described for 1878. The production of the works during the season of 1879, was about 170 000 barrels. The curve of results of tests of cement made in 1879 upon briquettes up to the age of six months, from this wooden mould (Curve B, Plate IX.), shows the advantage of this improved method of forming the briquette. The cement tested is believed to have been of the same general average quality as that of 1878.

Referring now to the general results of the tests of this American cement as given herewith, and comparing them with the tests of other cements, as for example, the foreign Portland, a comparison can be made as to the effective and economical use of these cements for various purposes.

Very full tests have been made of various brands of Portland cement,

notably by Mr. John Grant, in London, from 1859 to 1868. Results from these tests, running from seven days to seven years are shown in the accompanying table, which is from the paper by John Grant, Trans. Inst. C. E. London :

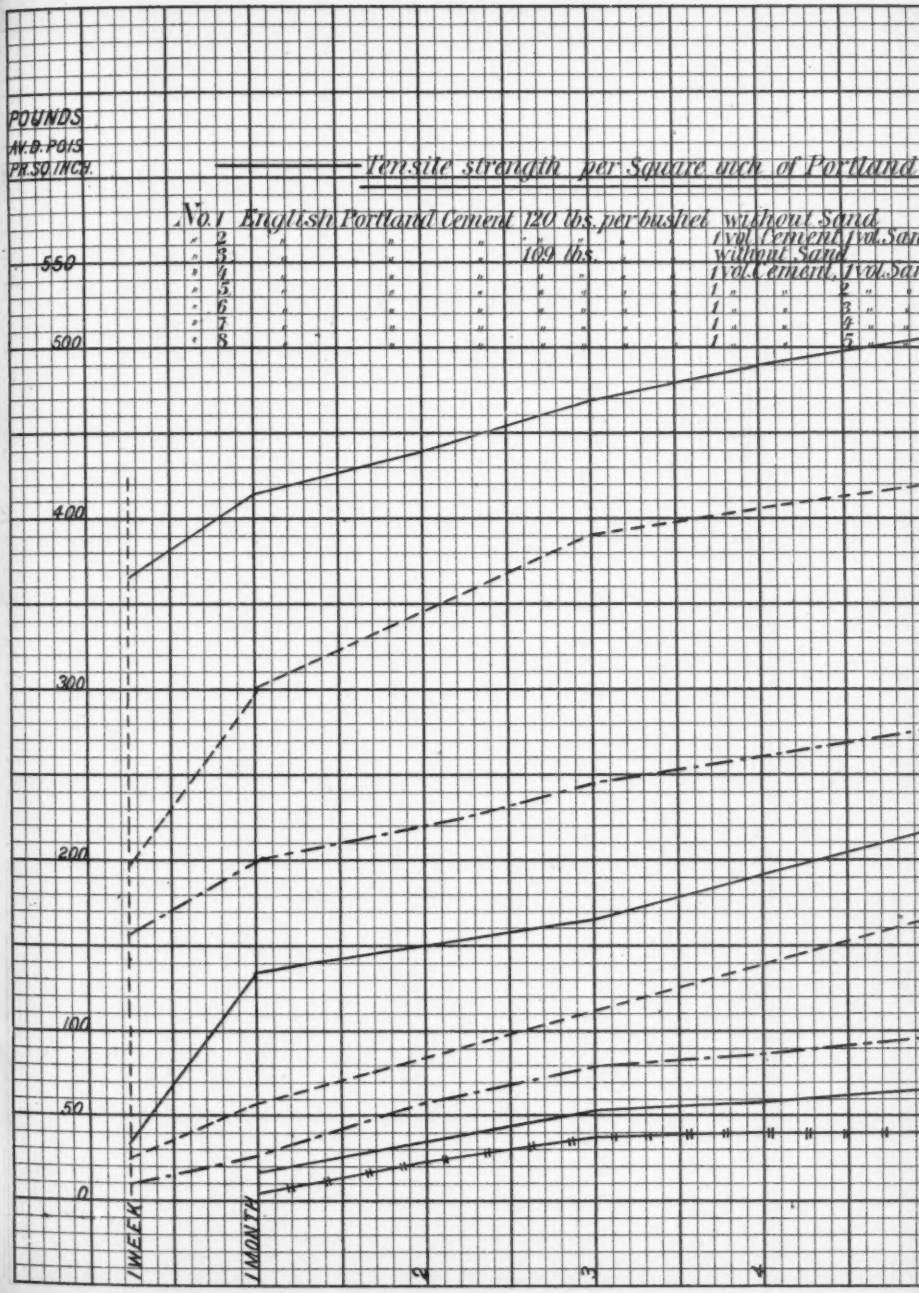
PORTLAND CEMENT.

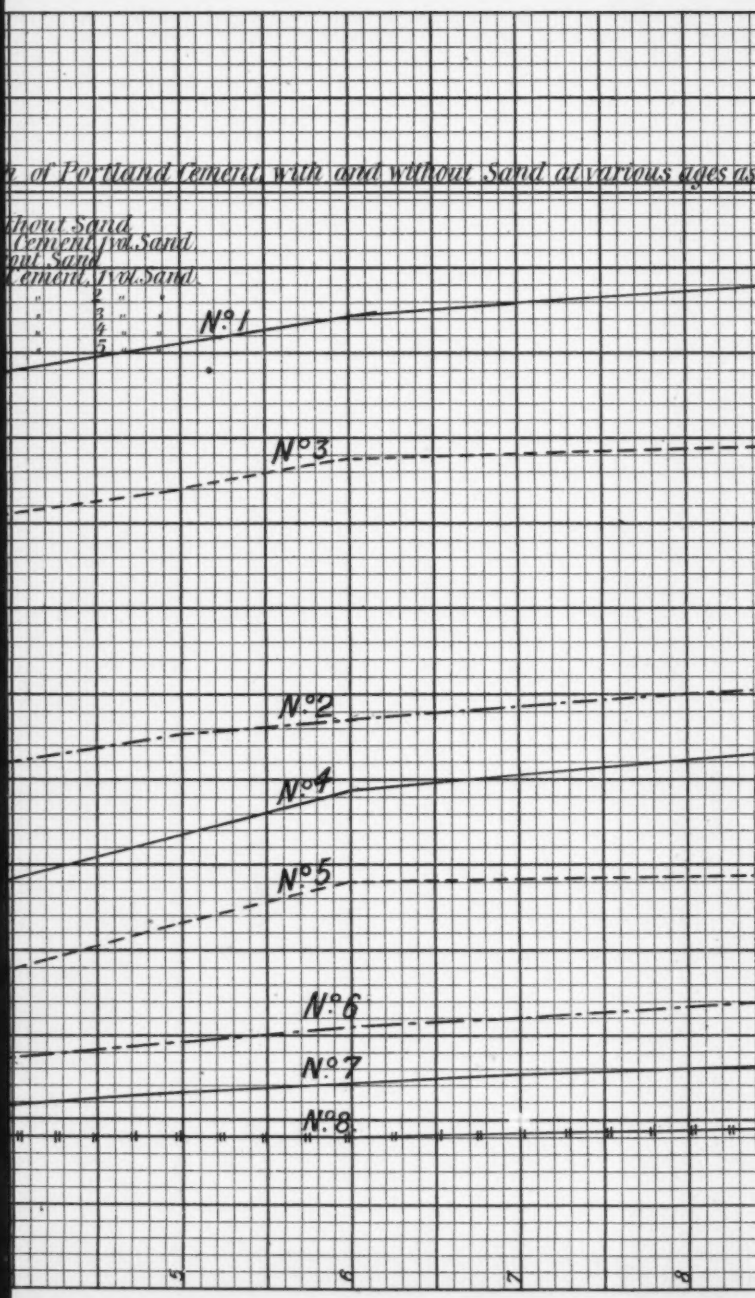
Age.	Neat cement, average breaking test of ten experiments. Lbs. per square inch.	One of cement to one of sand, average breaking test of ten experiments. Lbs. per square inch.
7 days	363.1	157.0
1 month	415.9	201.1
3 "	469.3	243.3
6 "	522.9	284.6
9 "	542.0	307.7
12 "	546.5	317.6
2 years	588.8	351.2
3 "	584.2	348.8
4 "	583.4	363.6
5 "	580.4	364.9
6 "	581.3	364.2
7 "	589.9	383.8

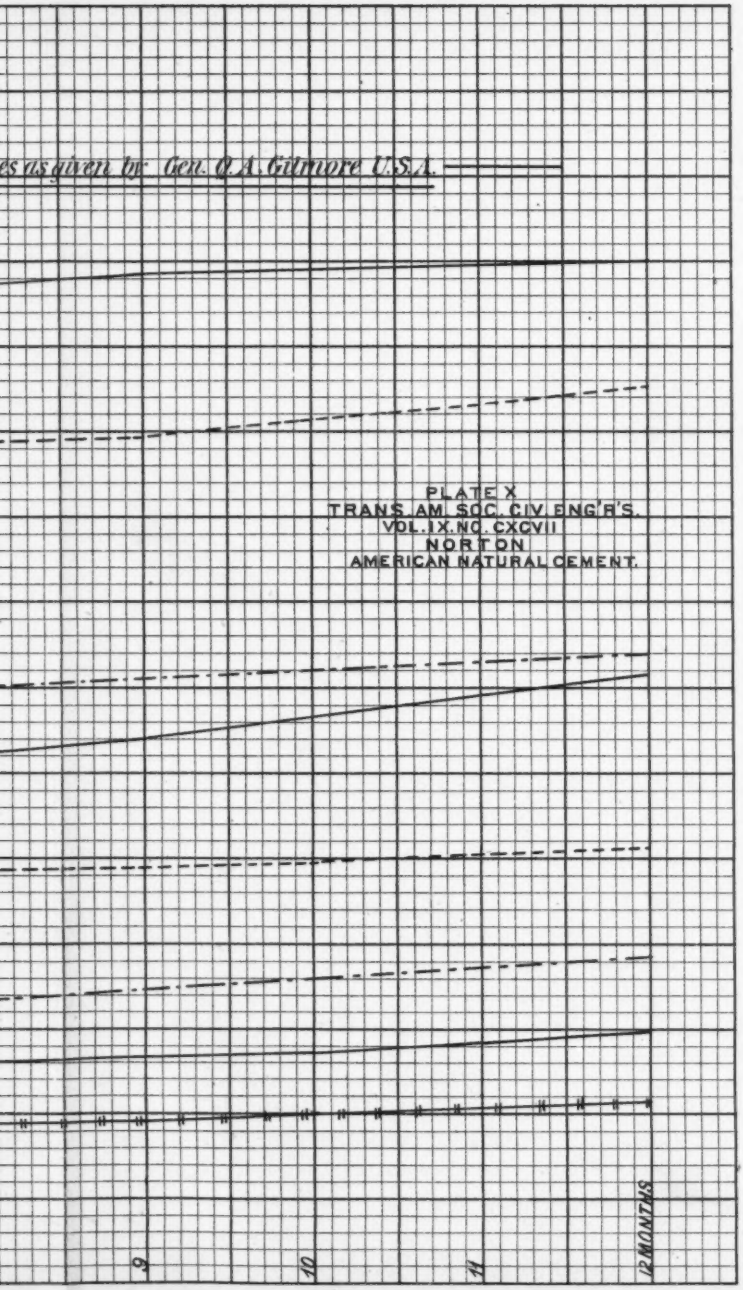
The strength of Portland cement, unmixed with sand, is, of course, very great. It developes a large proportion of its ultimate strength in the first seven days, say from one-half to two-thirds.

Rosendale cement of the best qualities developes great hydraulic energy in twenty-four hours, being at that time equal to the Portland. The Portland then gains very rapidly upon it up to seven days, the difference between the two then being the greatest; at the end of a month, however, the strength of the Rosendale cement begins to approach nearer to that of the Portland, and the difference between the two seems to be continually reduced after that time, this referring to mixtures of pure cement.

For practical purposes, however, neither of the cements is generally used without an admixture of sand. The addition of sand to Portland cement reduces its strength rapidly, as is shown by the curves on Plate X. These curves are taken from the work on Coignet Beton, by Gen. Q. A. Gillmore, Member A. S. C. E.


POUNDS AV.D. PER SQ.INCH.
Tensile strength per Square inch of Portland
No.1 English Portland Cement 120 lbs. per bushel without Sand
" 2 " " " " " " " 1 vol. Cement 1 vol. San
" 3 " " " " 109 lbs. " " without Sand
" 4 " " " " " " " 1 vol. Cement 1 vol. Sa
" 5 " " " " " " " 1 " " 2 " "
" 6 " " " " " " " 1 " " 3 " "
" 7 " " " " " " " 1 " " 4 " "
" 8 " " " " " " " 1 " " 5 " "
550
500
400
300
200
100
50
0
1 WEEK
1 MONTH
2
3
4


of Portland Cement, with and without Sand at various ages as
thout Sand.
Cement 1vol. Sand.
out Sand
Cement 1vol. Sand.
" 2 " "
" 3 " "
" 4 " "
" 5 " "
N°1
N°3
N°2
N°4
N°5
N°6
N°7
N°8
5
6
7
8


es as given by Gen. G.A. Gilmore U.S.A.
PLATE X
TRANS. AM. SOC. CIV. ENG'R'S.
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NORTON
AMERICAN NATURAL CEMENT.
9
10
11
12 MONTHS

This reduction of strength is in round numbers, as follows :

1	part of	sand	gives	mortar	½	as strong as	pure cement.
2	"	"	"		⅓	"	"
3	"	"	"		¼	"	"
4	"	"	"		⅕	"	"
5	"	"	"		⅙	"	"

The reduction of strength of Rosendale cement by the admixture of sand seems to be somewhat less. The strength of a mortar formed by the mixture of one portion of Rosendale cement with one portion of sand has been tested, and the result of these tests is shown in Plate XI. The strength of the mortar of Portland cement in the proportion of one of cement to two of sand is, at the end of six months, say 224 pounds to the square inch, also shown in Plate XI.* The strength of a mortar of Rosendale cement in the proportion of one of cement to one of sand is, at the end of six months, say 257 pounds to the square inch.

Careful experiments made by General Gillmore, and published in the Appendix to the last edition of his treatise on "limes, hydraulic cements and mortars," give the quantities of mortar produced from the mixture of cement, sand and water, in various proportions, and using different kinds of cement. Adopting these results, and assuming the cost of the Rosendale cement at $1.10 per barrel, and the best English Portland at $3 per barrel (the market prices May, 1880), and the cost of sand at five cents per barrel, we find that a mortar of Portland cement in the proportions of one of cement to two of sand† will cost per barrel $1.22.

We also find that a mortar of Rosendale cement in the proportions of one of cement to one of sand will cost $0.68‡ per barrel.

Summarizing the comparison, we find that a mortar of Rosendale cement in the proportions of one of cement to one of sand has a tensile strength of 257 pounds to the square inch, and costs $0.68 per barrel; and that a mortar of foreign Portland cement, in the proportion of one of cement to two of sand, has a tensile strength of 224 pounds to the square inch, and costs $1.22‖ per barrel.

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* Clarke's Experiments—Boston sewerage.

† One barrel Portland cement and two barrels of sand give give 2.54 barrels mortar.—Gillmore.

‡ A mortar made from American Portland cement (at a price of $2.50 per barrel) in the proportion of one of cement to two of sand will cost $1.02 per barrel.

‖ A mortar of American Portland cement in the proportions of one of cement to two of sand has a tensile strength of 192 pounds to the square inch, and costs $1.02 per barrel.

Therefore, the mortar of Rosendale cement, one to one, is 34 pounds per square inch stronger, and $0.54 per barrel less expensive than a mortar of foreign Portland cement one to two.

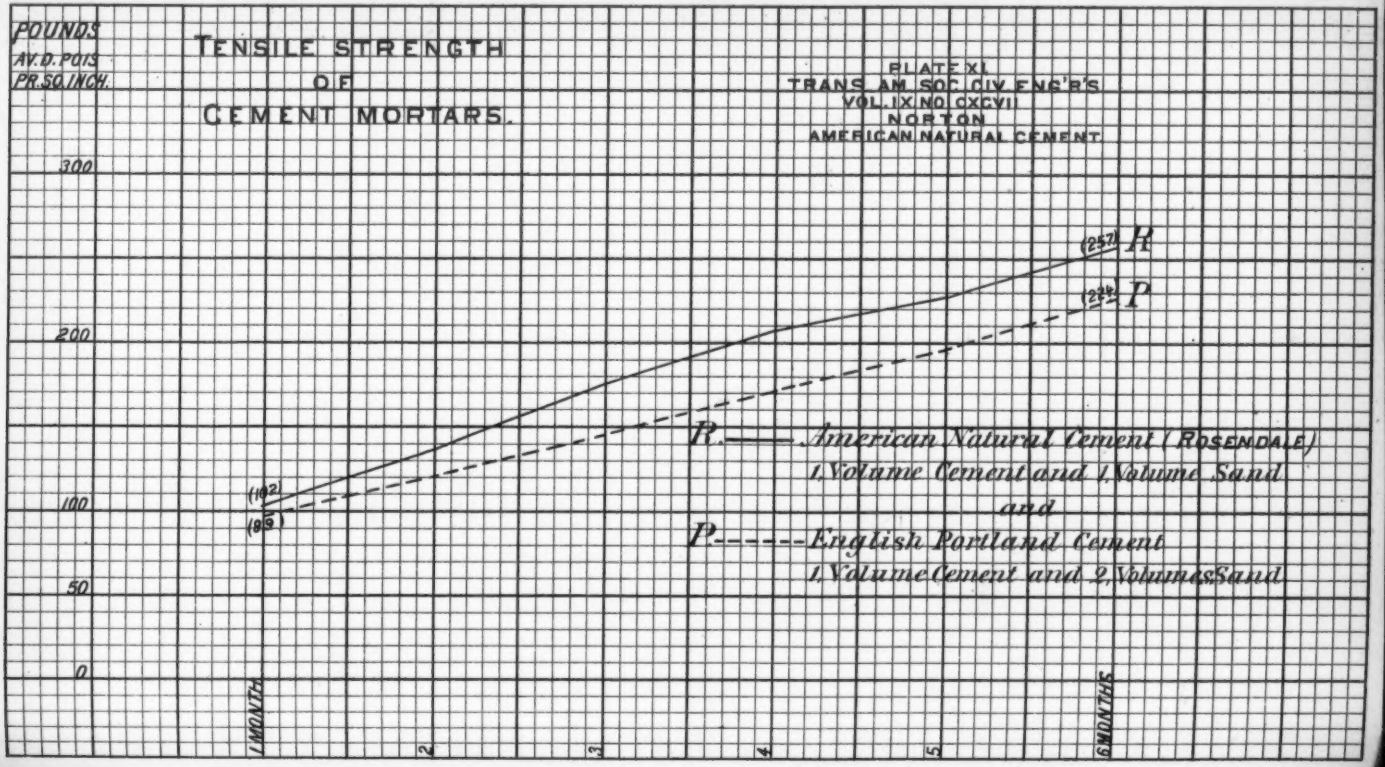
This seem to show that for all uses which will be served by a mortar of the tensile strength of 257 pounds per square inch, the Rosendale cement is economical.

The remaining question is, whether this mortar of Rosendale cement, one to one, is strong enough for the practical purposes to which it may generally be applied.

The facts which answer this question are that for fifty years past, and up to within a very short time *all* the important masonry in this country has been laid with American cement. The great fortifications on the coast, the Croton Aqueduct, the Boston Aqueducts, both old and new, all the government dry docks, the light-houses, the locks, culverts and aqueducts on the Erie and other canals; all the masonry of rail-road bridges, viaducts and culverts, the sewers of our cities, the masonry of our gas-works, many hundreds of miles of wrought iron water-pipe lined and laid in cement; the mills and mill dams in various localities; in fact, nearly all the masonry built under water and out of water in the United States up to within a few years has been constructed with American cement.

The standard of strength for American cement during most of these years past was not as high as it now is, and only in specially important situations was the mortar made as rich as one to one.

The result of this use of American cement has been very generally satisfactory. As a proper economy in the use of the materials of construction is one of the essential elements of good engineering, the writer has ventured to submit these somewhat extended tests, made originally entirely because he believed that, as a manufacturer of cement, it would be in all respects advantageous to improve its quality and maintain a high standard for its strength. He has ventured also to present to the Society some deductions which seem to fairly follow the results of the tests.


POUNDS AV. D. POIS PR. SQ. INCH.
TENSILE STRENGTH OF CEMENT MORTARS.
PLATE XI
TRANS. AM. SOC. CIV. ENG'R'S
VOL. IX NO. CXCVII
NORTON
AMERICAN NATURAL CEMENT
300
200
100
50
0
(257) R
(224) P
(102)
(89)
R.—— American Natural Cement (ROSENDALE)
1 Volume Cement and 1 Volume Sand
and
P.------ English Portland Cement
1 Volume Cement and 2 Volumes Sand
1 MONTH
2
3
4
5
6 MONTHS

AMERICAN SOCIETY OF CIVIL ENGINEERS.

INSTITUTED 1852.

TRANSACTIONS.

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(Vol. IX.—July, 1880.)

DISCUSSION

By ASHBEL WELCH, Member of the Society, upon Paper CLXXXIX.

THE ENGINEERING PROBLEMS INVOLVED IN THE PROPOSED IMPROVEMENT OF THE ERIE CANAL, BY INCREASING THE DEPTH OF ITS CHANNEL ONE FOOT.*

I wish to call attention to a single point, suggested by Mr. Sweet's paper, giving experiments on the resistance to the motion of boats in a canal. He cites a formula of Du Buat, which, if I understand it aright, fails to take into consideration a very material circumstance. It makes the resistance of the vessel dependent on the relative areas of the immersed section of the vessel, and of the cross section of the channel, without taking any notice of the form of the channel, or of the vessel.

If you watch a boat passing through, and very near one side, of a lock or aqueduct much wider than the boat, you will see that the cur-

* Paper CLXXXIX, by E. SWEET, Jr., Member A. S. C. E. Vol. IX. March, 1880.

rent running in the direction opposite to that in which the boat moves, is several times as great through the narrow space, as through the wide one. So where the bottom of a boat is close to the bottom of a channel. the backward current under the bottom is vastly greater than that between the boat and the more distant boundaries or sides of the channel. This is shown by the force with which the water boils up under the stern, and by the coarseness of the particles of sand torn by the violence of the current from the bottom, and thrown up in the wake of the boat.

By the formula of Du Buat, unless I misunderstand its conditions, the resistance is assumed to be as the square of the velocity of the whole amount of the water flowing backwards past the boat, that is, as the square of the average velocity. But if this whole amount is divided up into different currents, with different velocities, the sum of the squares of the velocities of these different currents multiplied by the amounts of surface whose friction must be respectively overcome, will be quite different from the square of the average velocity of the whole multiplied by the whole amount of resisting surface.

Suppose a flat-bottomed, vertical sided boat, 20 feet wide, drawing 5 feet of water, and so having an immersed sectional area of 100 square feet, is moving 3 feet per second through a channel 6 feet deep, having 400 square feet sectional area, making the sections as 1 to 4. Then the wet perimeter of the boat will be 30 feet, and that of the channel, supposing its slopes are 1 to 1, not quite 78 feet. Then the average velocity of the counterflow, as I used to call it, required to send the water back to fill up the space left by the boat is 1 foot per second. The velocity of the current along the surface of the boat will then be $(3' + 1' =)$ 4 feet per second, and against the surface of the channel 1 foot per second. The resistances *from friction* would then be represented by $(4^2 \times 30) = 480 + (1^2 \times 78 = 78) = 558$.

But suppose, what would probably be approximately true, that the velocity under the bottom of the boat was 4 feet per second, and that on each side $(\overline{300 \times 1 - 20 \times 4} \div (300 - 20) =)$ 0.785 feet per second. The friction against the bottom of the boat is then $(4 + 3)^2 \times 20 = 980$, and against the sides $(0.785 + 3)^2 \times \overline{2 \times 5} =)$ 143, and the friction against the part of the bottom under the boat is $4^2 \times 20 = 320$, and against the rest of the bottom and the sides is $(0.78^2 \times \overline{78 - 20} =)$ 35. The aggregate of all these is 1 478, being 165 per cent. more than it would be if the counterflow in all parts of the channel had the same velocity.

Judging from my own early experience, and especially from experiment, in towing heavy barges in a canal by locomotive on a railroad on the bank, I think the difference is greater than I have stated. I am sorry I did not preserve the numerical results. When possible, we deepened the canal, so as to give two feet instead of one under the boats, and with very great advantage. One foot area of water section under the boat, was of more value than several feet anywhere else.

In making a single track ship canal, say for ships of 26 feet draft, the parts of it in which ships are not to pass each other, should not, as commonly proposed, be 70 or 80 feet wide at bottom and only 28 feet deep, but should, when practicable, have nearly as much water under the keel as on each side of the bilge. Suppose a ship has 45 feet beam and 26 feet draft, she would probably meet with fifty per cent. more resistance in a canal 160 feet wide on the surface and 28 feet deep with slopes of $1\frac{1}{2}$ to 1, than if the canal were 148 feet wide on the surface and 34 feet deep; the area of the water prism being just about the same, and the area of the excavation, if in a deep cut, very much less. With the deeper water the ship steers so much better that she is much less likely to graze the banks though nearer to them.

Of course there are cases where this cannot be done, as over culverts, and others where it would increase the risks, as on high embankments. But because the best section cannot be got all the way, it is no reason why it should not be wherever possible.

AMERICAN SOCIETY OF CIVIL ENGINEERS.

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CXCVIII.

(Vol. IX.—July, 1880.)

NOTES ON THE SOUTH PASS JETTIES.

By MAX E. SCHMIDT, Member of the Society.

READ AT THE TWELFTH ANNUAL CONVENTION, MAY 25TH, 1880.

WITH REMARKS

By JAMES B. EADS, Member of the Society.

At the request of Mr. E. L. Corthell, Resident Engineer, and as an addendum to the paper of the writer of last year,* the following brief notes are submitted relating to the maintenance of the channel at the South Pass Jetties, and the general condition of the works.

At the head of the passes the 30-feet channel is now 450 feet wide, with a least depth of 30.1 feet. The improvement during the last year has been constant and more marked than at any period heretofore.

At the Jetties proper the channel has again improved in depth and width. There has not been a single day in the last five months on which the 30-feet channel has been found deficient, and during that time the dredge boat *Bayley* has been in service only 11½ days, when work was required near the sea ends of the Jetties, where slight fluctuations in the bottom, nominally closing the 30-feet channel must be expected

* Paper CLXXXIII. The South Pass Jetties. Max E. Schmidt. Vol. VIII., Page 189. August, 1879.

to take place, owing to the action of the waves and the effect of storms upon the mouth. But the consolidating works now in progress at the ends of the jetties once completed, there will be a permanent central depth of 30 feet and more, which will be wholly maintained by the action of the current, and require no dredging.

No examination has been made of the Gulf bottom immediately seaward of the Jetties since December, 1879, when a comparison with the survey of 1876 showed an average scour of 770 087 cubic yards, amounting in total to an average increase of depth of 1.22 feet. Since 1875 the increase in depth over an area almost identical with the one just named, has been one foot and one-tenth.

The construction of the concrete capping on the East Jetty is nearly finished, including the parapet which crowns the blocks.

The concrete work will ultimately extend over a distance of 5 159 lineal feet, commencing at a point 6 500 feet from the eastern Lands-end and terminating at the sea end.

The net amounts of material used in the construction of the Jetties are as follows :

13 000 000 feet B. M. of lumber.
600 000 cubic yards of willows.
100 000 " " of stone.
6 881.47 cubic yards of concrete for blocks and parapet.
375 000 feet B. M. of palmetto logs.

A complete history of the entire works is now being prepared by Mr. Corthell which will give all facts of interest to the profession and fully and freely discuss all questions connected with the works.

JAMES B. EADS : I have but little to add of interest to what is contained in the statement just read. The statement is substantially correct.

I may remark that the depth which is given at the head of the pass, 30 feet and one-tenth, is measured on the plane of low water of the river. The average or mean flood tide is the plane which is referred to for all measurements of depth; but at the head of the pass that plane is established at the average flood tide of low water of the river. It makes a difference of two to three feet in depth. We have at this time about two feet depth additional to that which is reported; that is, through the head of the pass, where we had a shoal of 14 feet, and the removal of which shoal constituted the most important problem that

had to be solved, we have now 32 feet. The channel has been deficient occasionally at the sea end of the Jetties to such an extent as to require a few hours' use during the day of the dredge boat *Bayley* to remove it. It is caused by the fluctuation of the winds and waves. The volume of water which goes through the pass is capable of maintaining a certain section; if that section becomes too flat the 30 feet channel is likely to fail. We have to maintain a certain width of 26 feet water. That width must be 200 feet, and through the centre of that there must be 30 feet. We sometimes have too much 26 feet water, it gets too wide, and then the 30 feet channel shallows up a little near the ends. The inspecting officer has no discretion in the premises; and if he reports either one of the dimensions deficient, the payment stops, and only commences again when the channel is restored. The channel has, I believe, 32 or 33 feet as the least depth throughout the whole two and one-fourth miles of Jetty channel, with the exception of, probably, 300 or 400 feet near the sea end of the Jetties. That part of the Jetties is not yet entirely completed. We are consolidating the east Jetty. The west Jetty is finished, and those consolidated works are required to be extended probably 150 feet.

There is a very large amount of water round the end of the consolidated works, extended as far as they have been, and as they are extended to the end the part that is likely to fail being above that or immediately abreast of it, that will be corrected, and we will have, I think, 32 or 33 feet depth as the least depth throughout the channel in the course of two years. The channel is slowly enlarging; it is enlarging more slowly now under the action of the current than it has hitherto; as the equilibrium of forces is gradually restored it is restored more slowly; and that will result in a channel I think, at least 32 feet as the least depth throughout the work.